The new ECMWF Seasonal Forecast System (System-4)

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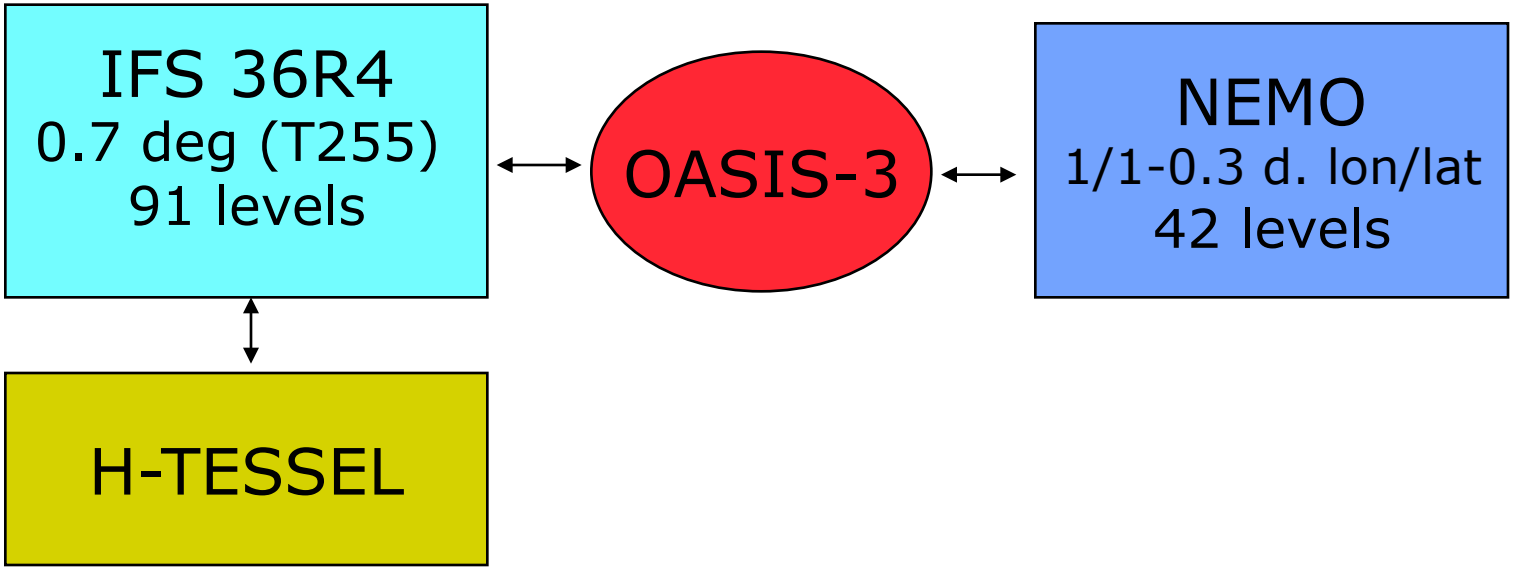
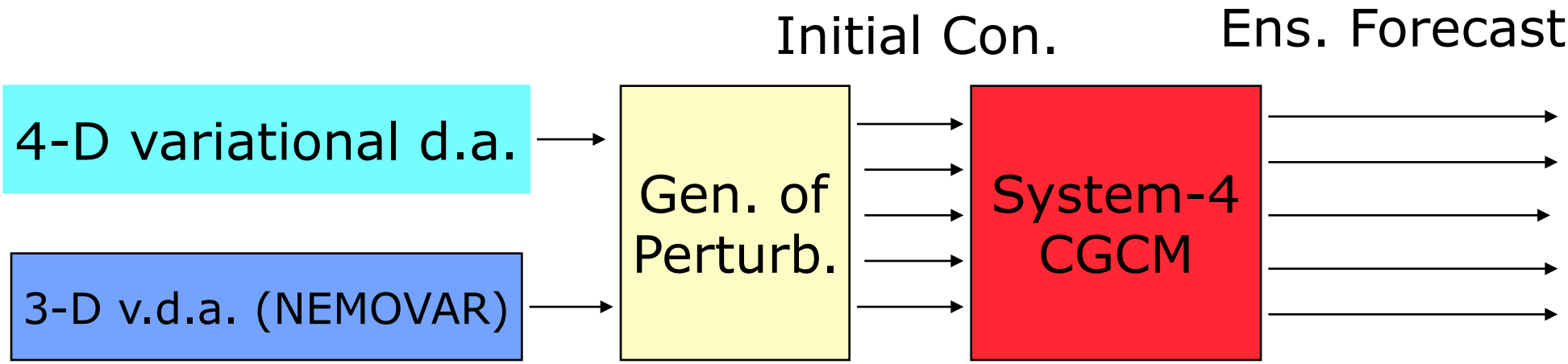
The new ECMWF Seasonal fc. system (Sys-4)





ECMWF System 4: main features (1)

- **New ocean model : NEMO v. 3.0 + 3.1 coupling interface**
  - ORCA-1 configuration (~1-deg. resol., ~0.3 lat. near the equator)
  - 42 vertical levels, 20 levels with z < 300 m

- **Variational ocean data assimilation (NEMOVAR)**
  - 3-D var with inner and outer loop
  - Collaboration with CERFACS, UK Met Office, INRIA
  - First re-analysis (1957-2009), no assim. of sea-level anomalies
  - Final re-analysis (ORA-S4) and real-time system including SLA

- **IFS model cycle: 36r4** (op. Nov. 2010-May 2011), **T255-L91**
  - New physics package, including H-TESSEL land-surface scheme, new snow model, new land surface initialization

- **Prescribed sea-ice conc. with sampling from recent years**

ECMWF System 4: main features (2)

- **Operational forecasts**
  - 51-member ensemble from 1st day of the month
  - released on the 8th
  - 7-month integration

- **Experimental ENSO outlook**
  - 13-month extension from 1st Feb/May/Aug/Nov
  - 15-member ensemble

- **Re-forecast set**
  - 30 years, start dates from 1 Jan 1981 to 1 Dec 2010
  - 15-member ensembles, 7-month integrations
  - 13-month extension from 1st Feb/May/Aug/Nov

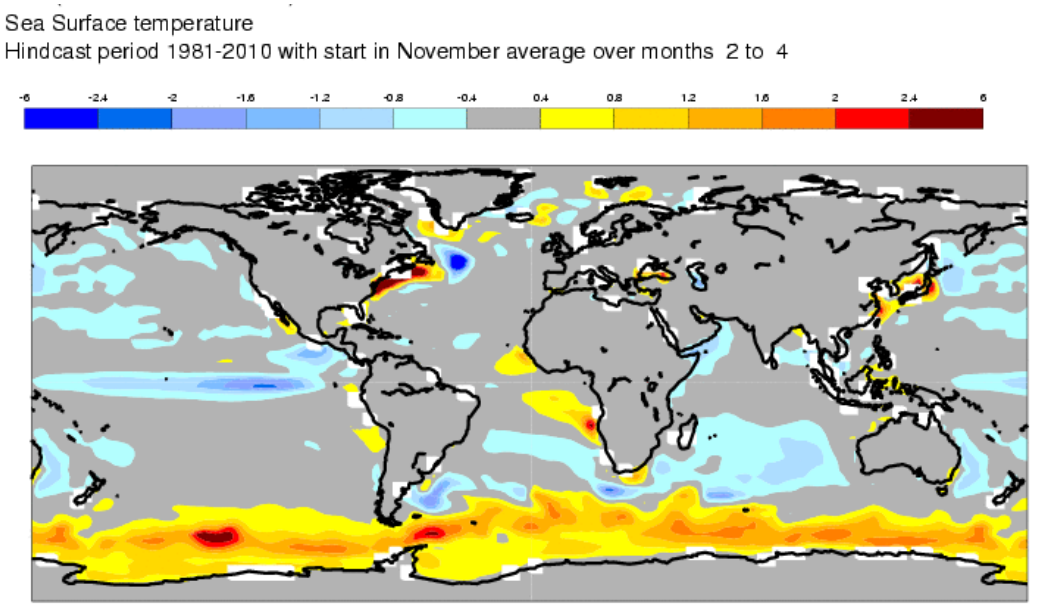
Bias in S4 re-forecasts: SST (DJF)

Start: 1 Nov.

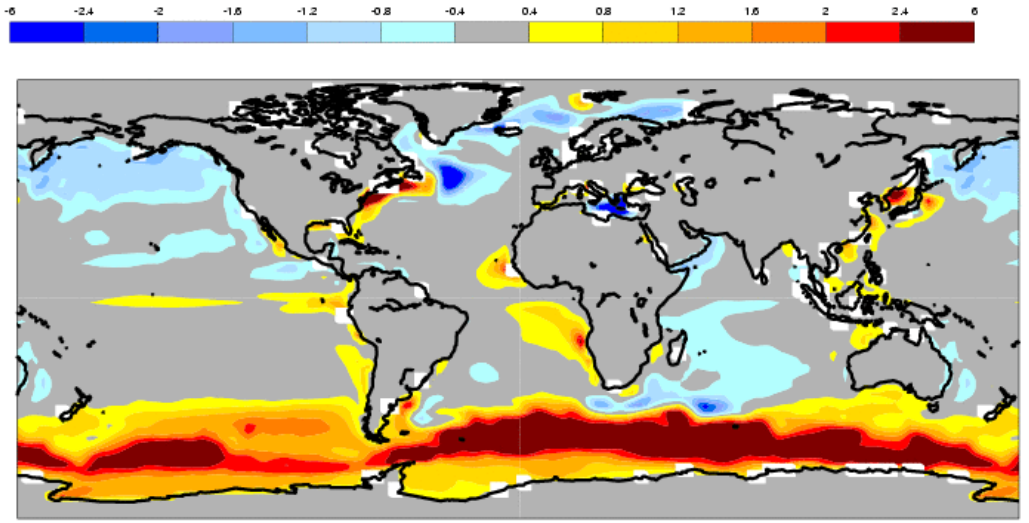
1981/2010

Verify: Dec-Feb

System 4



System 3



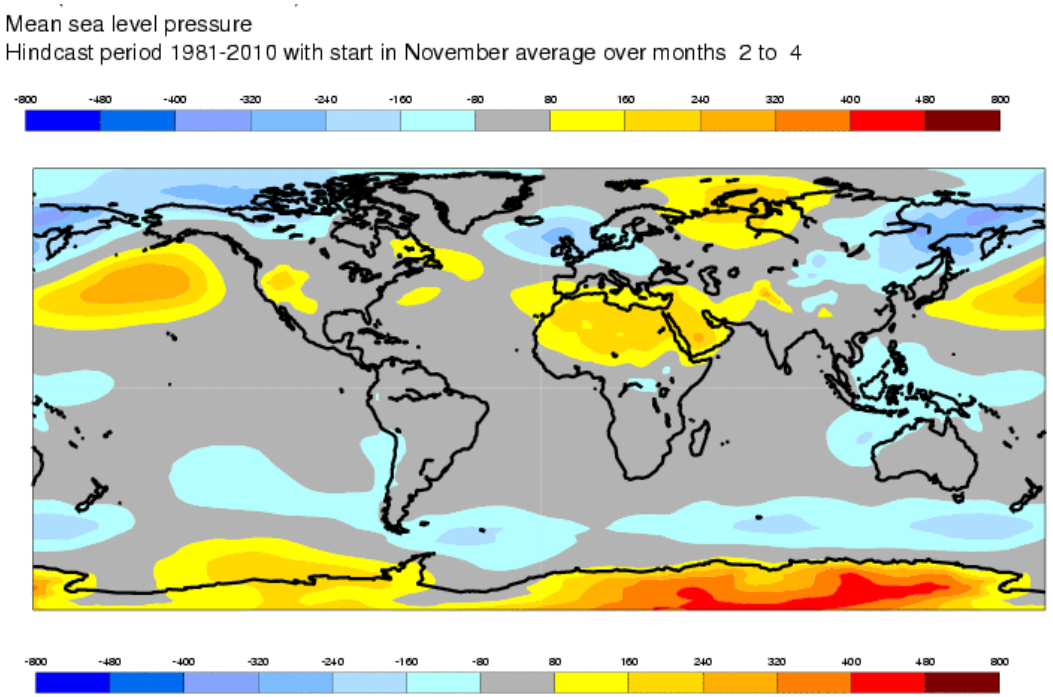
Bias in S4 re-forecasts: MSLP (DJF)

Start: 1 Nov.

1981/2010

Verify: Dec-Feb

System 4



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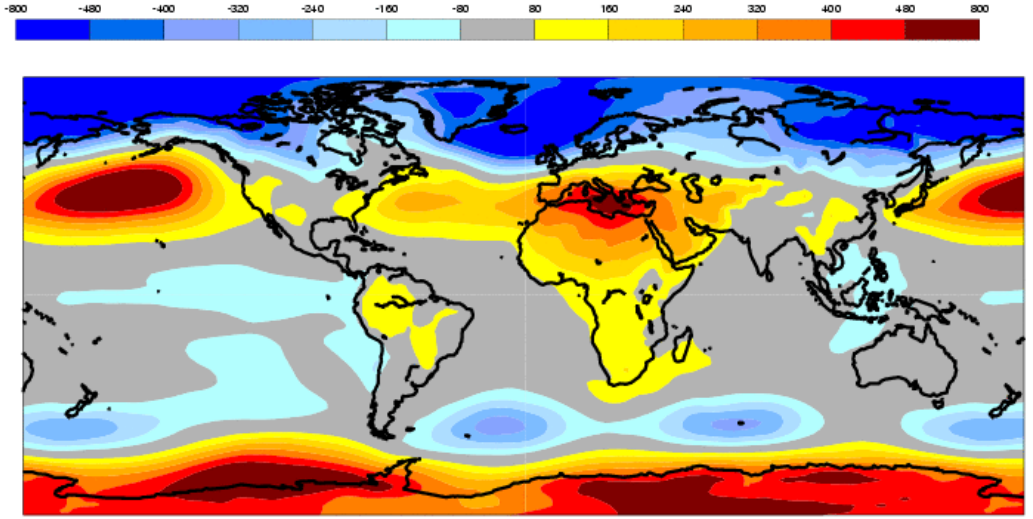


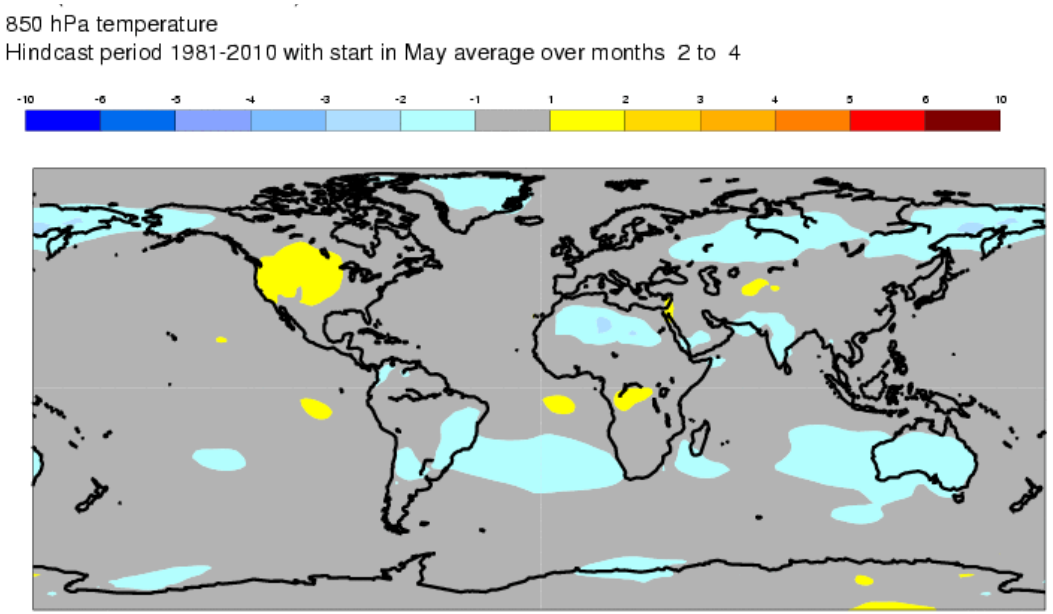
Bias in S4 re-forecasts: T 850 hPa (JJA)

Start: 1 May

1981/2010

Verify: Jun-Aug

System 4



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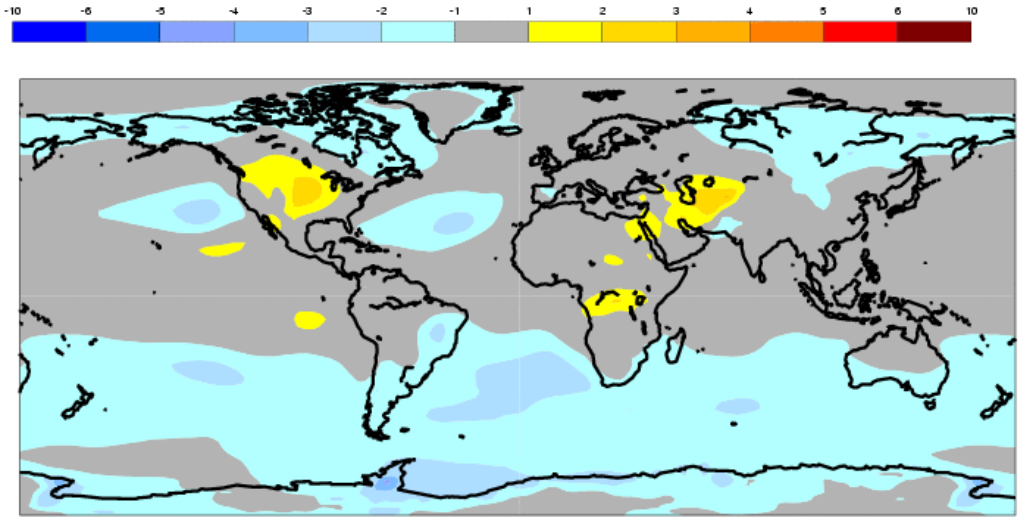


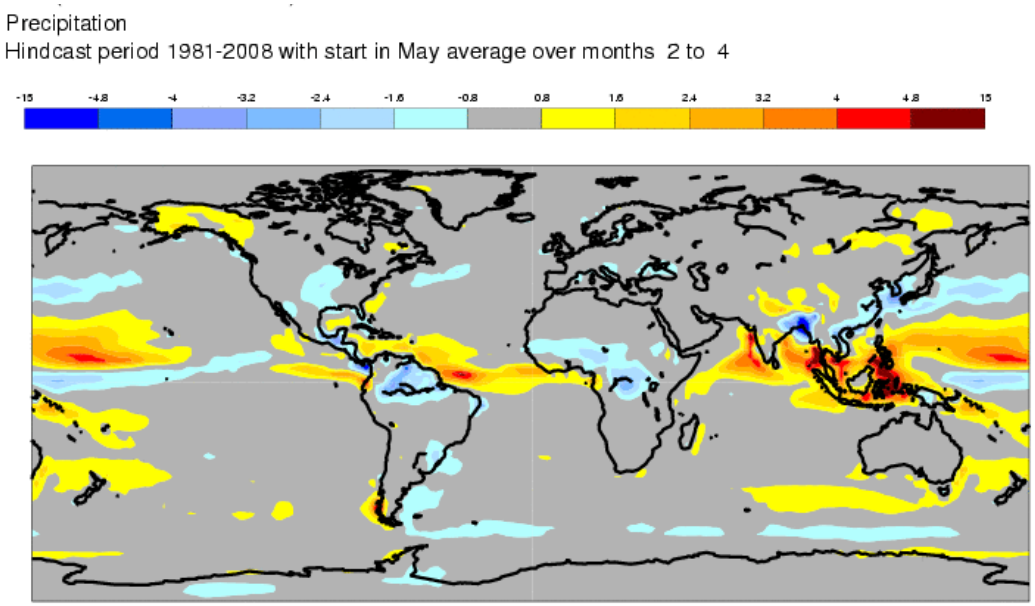
Bias in S4 re-forecasts: rainfall (JJA)

Start: 1 May

1981/2010

Verify: Jun-Aug

System 4



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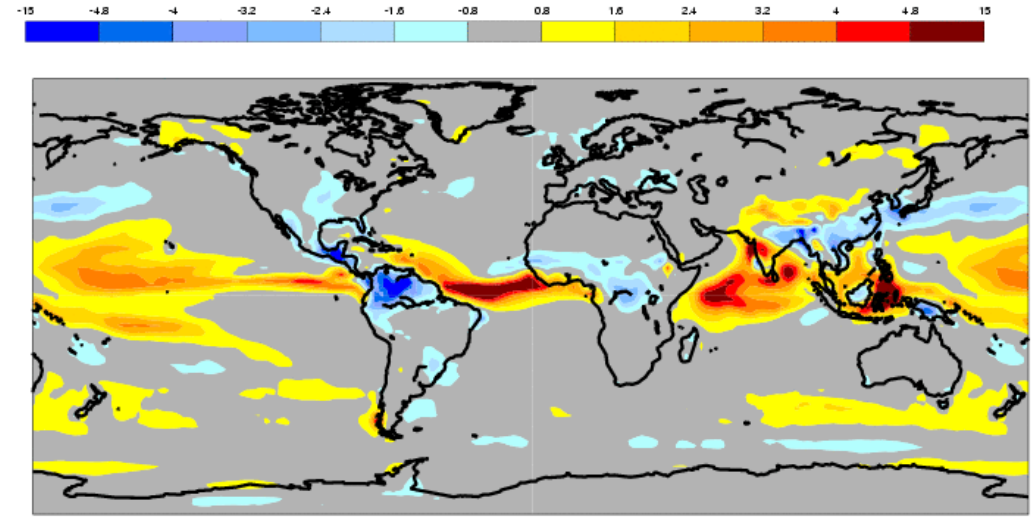
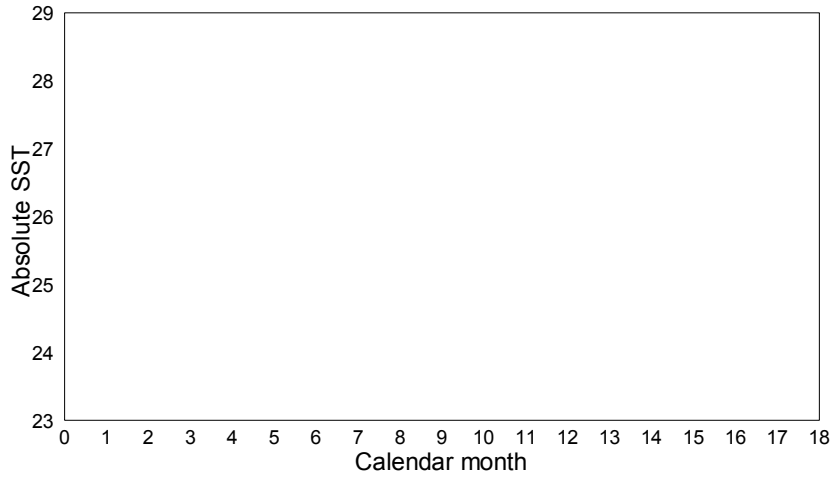
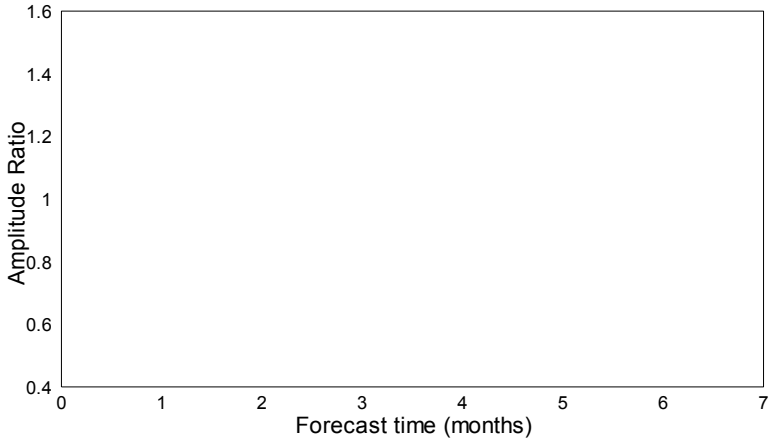


Errors in mean and variance of ENSO indices

NINO3.4 mean absolute SST

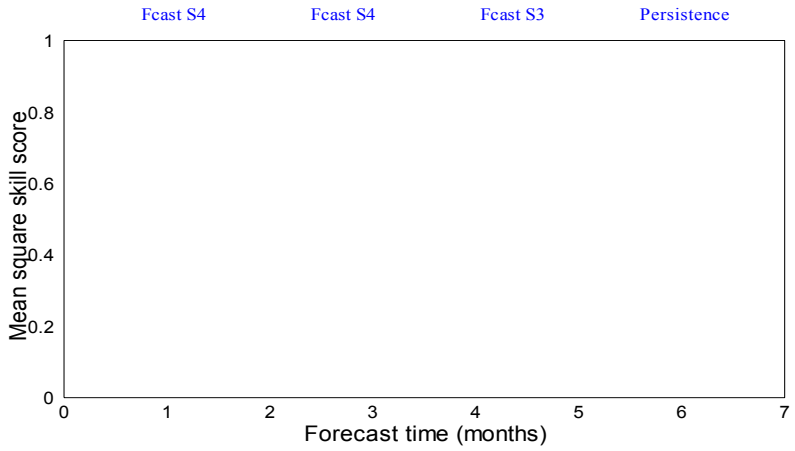


NINO3 SST anomaly amplitude ratio

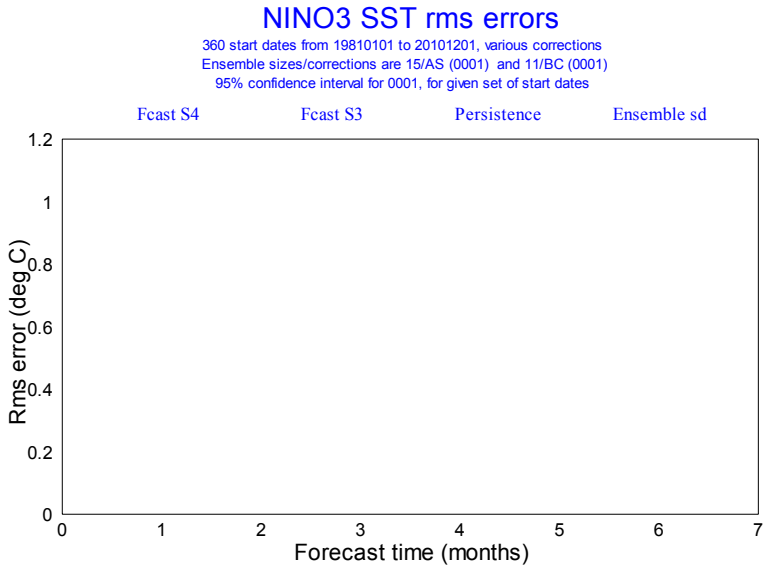


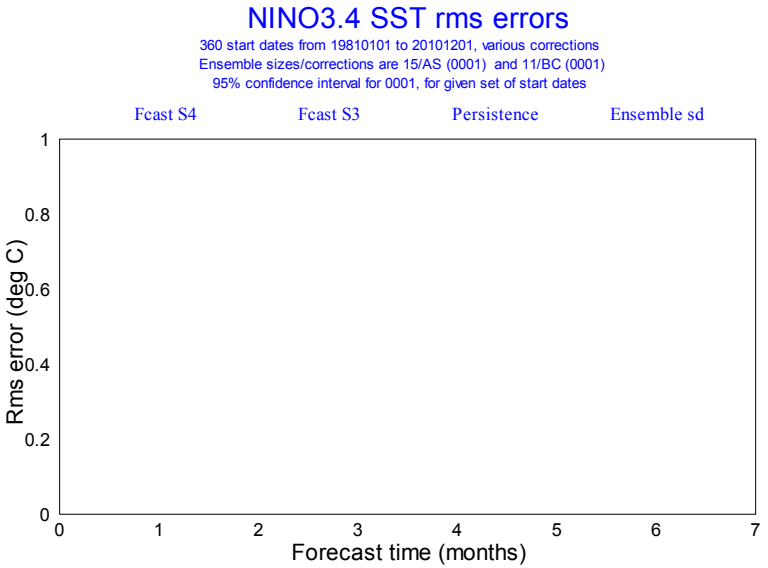
NINO3 SST mean square skill scores

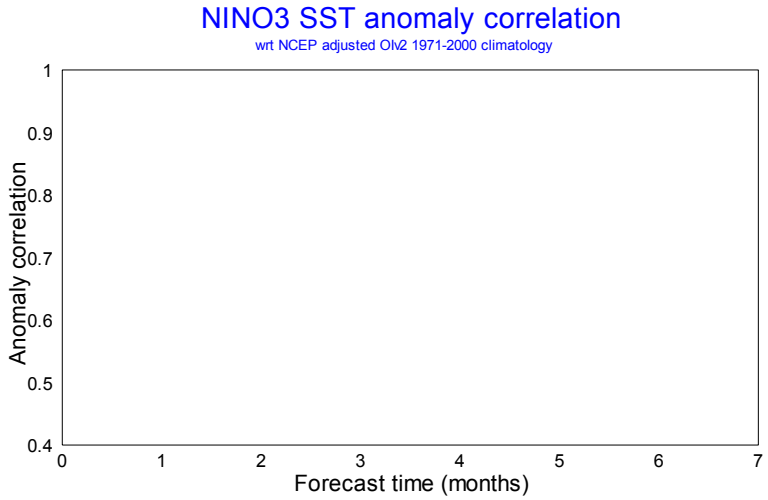
150 start dates from 19910201 to 20081101, various corrections
Ensemble sizes are 15 (0001), 11 (0001) and 11 (0001)

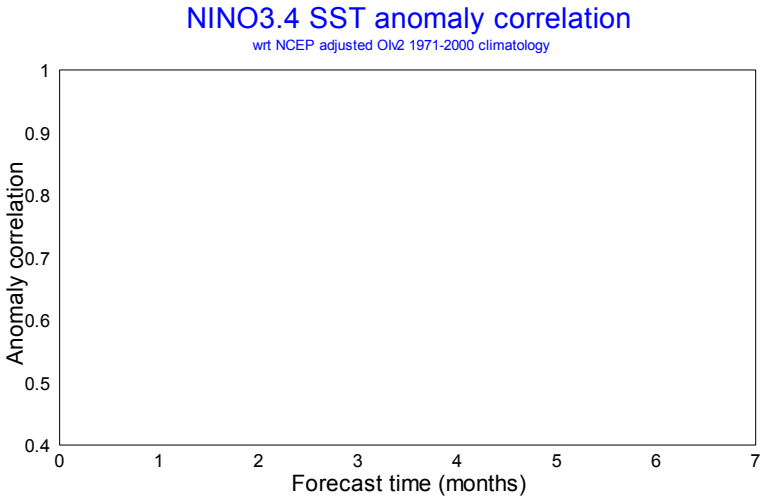


SST scores: Nino 3 and 3.4

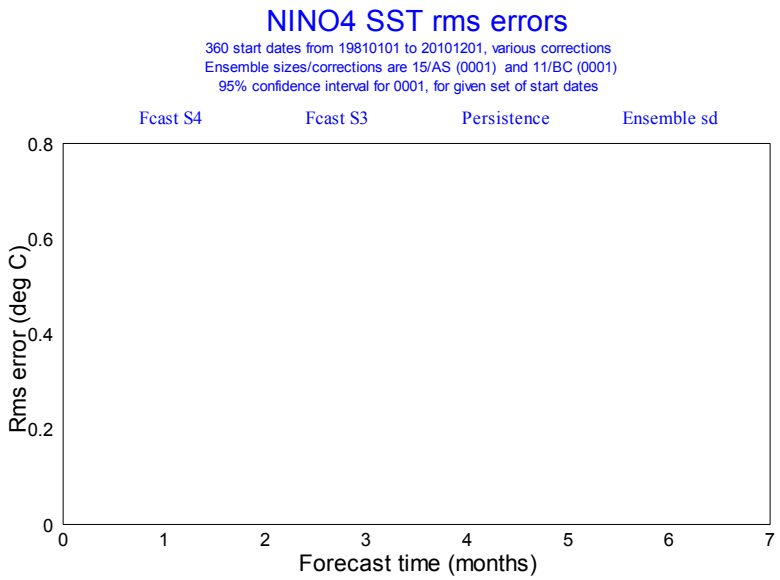


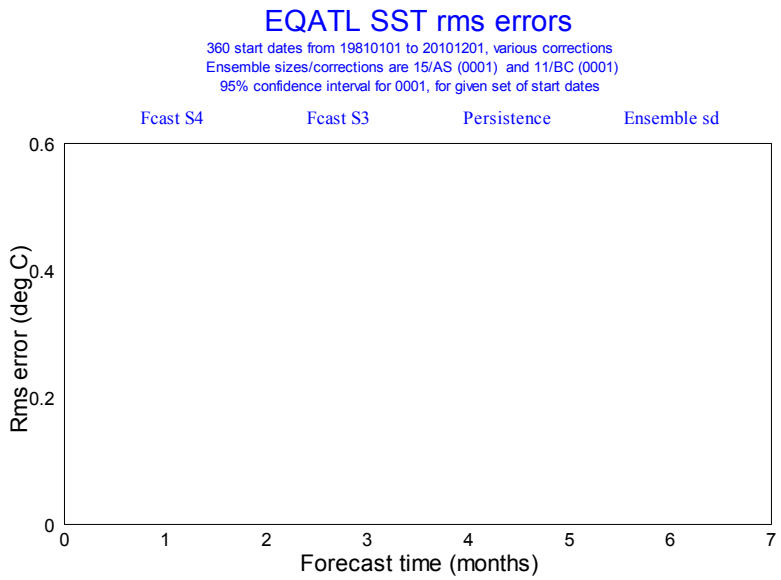


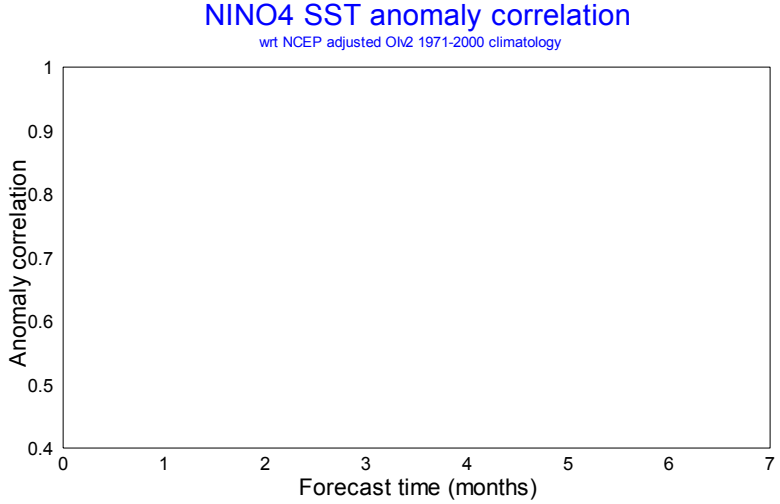


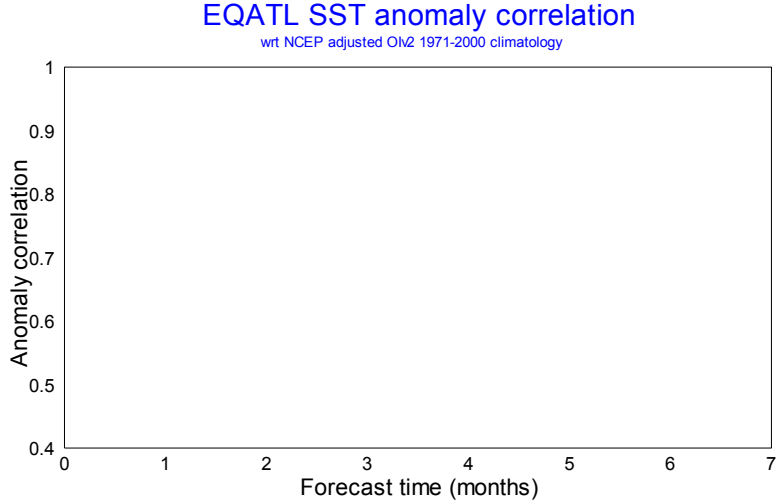


SST scores: Nino 4 and Eq. Atlantic









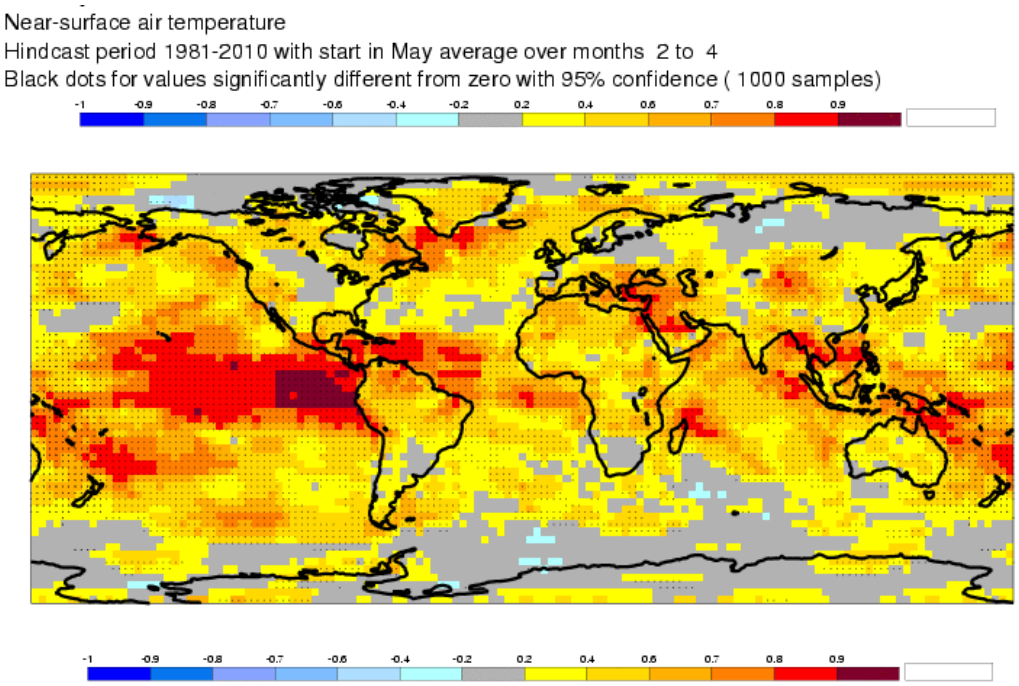
Ens-mean ACC in S4 re-forecasts: 2m T (JJA)

Start: 1 May

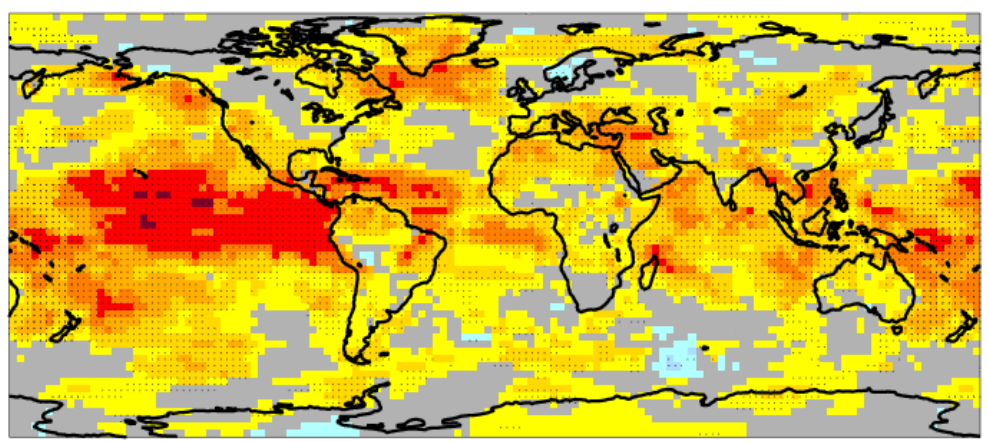
1981/2010

Verify: Jun-Aug

System 4



System 3



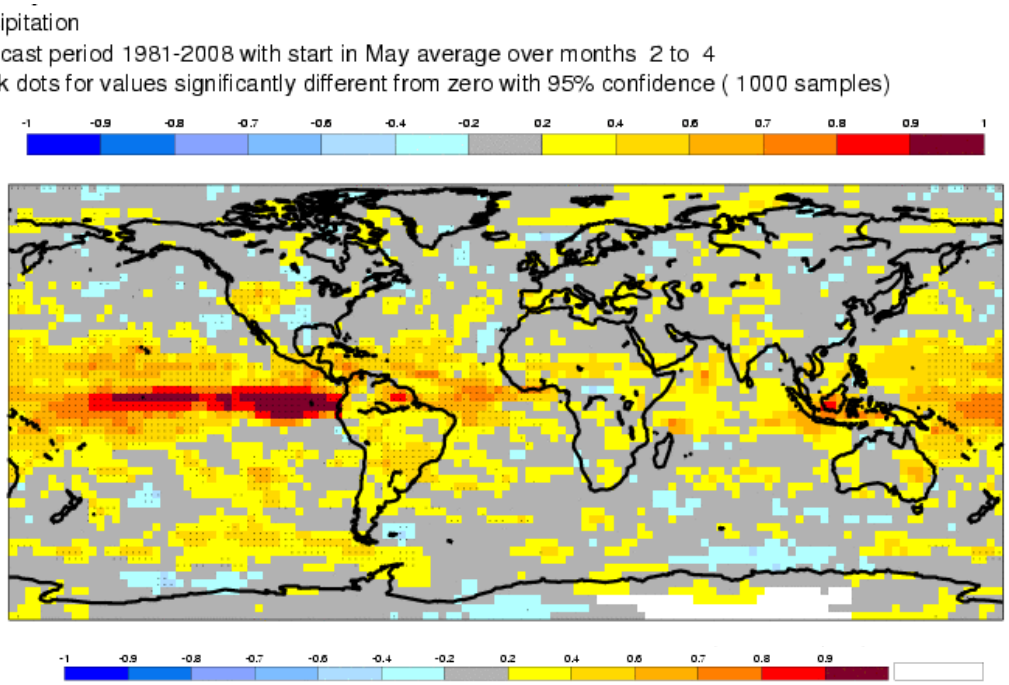
Ens-mean ACC in S4 re-forecasts: rainfall (JJA)

Start: 1 May

1981/2010

Verify: Jun-Aug

System 4



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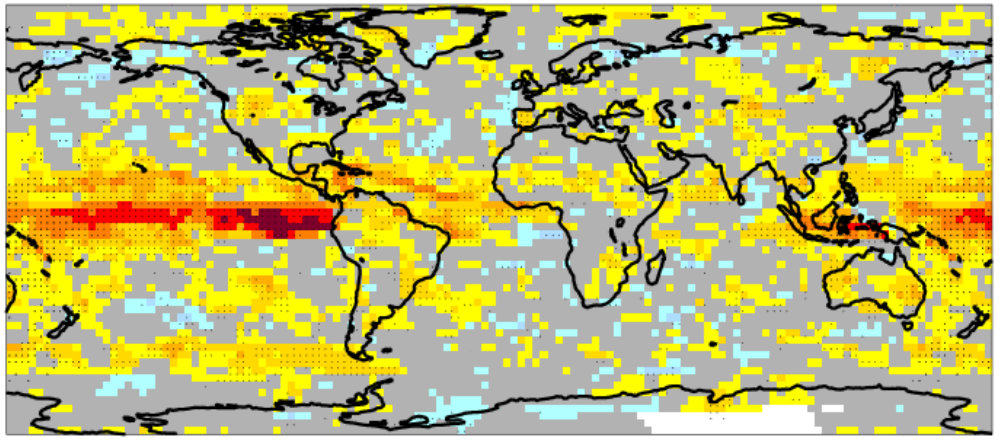


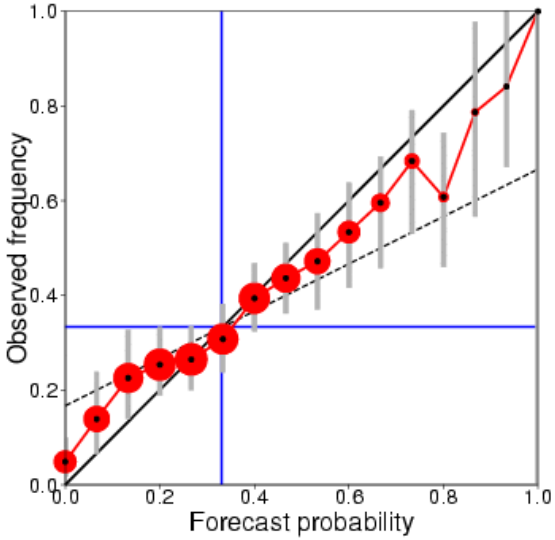
Averages of grid-point ACC

Field	Lead (months)	S3 mean	S4 mean	S4 wins
Tropics T850	1	0.573	**0.605**	12/12
Tropics T2m	1	0.601	**0.635**	12/12
NH Z500	1	0.246	**0.270**	7/12
NH T850	1	0.266	**0.306**	10/12
NH T2m	1	0.345	**0.375**	10/12
Tropics T850	4	0.443	**0.509**	11/12
Tropics T2m	4	0.431	**0.492**	12/12
NH Z500	4	0.167	**0.221**	11/12
NH T850	4	0.192	**0.249**	11/12
NH T2m	4	0.240	**0.287**	10/12

Reliability: 2m T > upper tercile over Europe, JJA

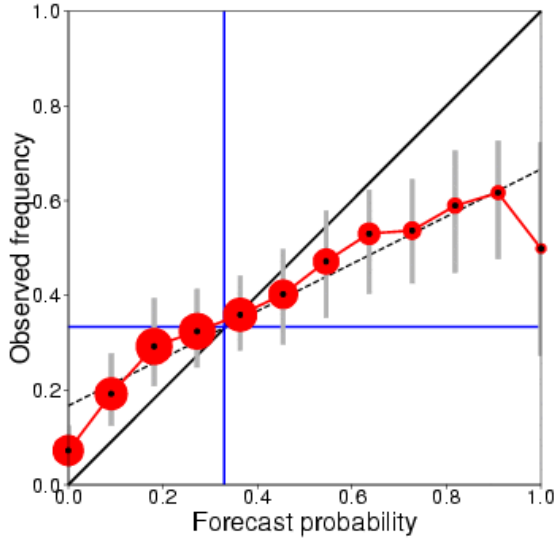
Sys 4

Reliability diagram for ECMWF with 15 ensemble members
Near-surface air temperature anomalies above the upper tercile
Accumulated over Europe (land and sea points)
Hindcast period 1981-2010 with start in May average over months 2 to 4
Skill scores and 95% conf. intervals (1000 samples)
Brier skill score: 0.092 (0.007, 0.162)
Reliability skill score: 0.986 (0.950, 0.994)
Resolution skill score: 0.106 (0.056, 0.173)

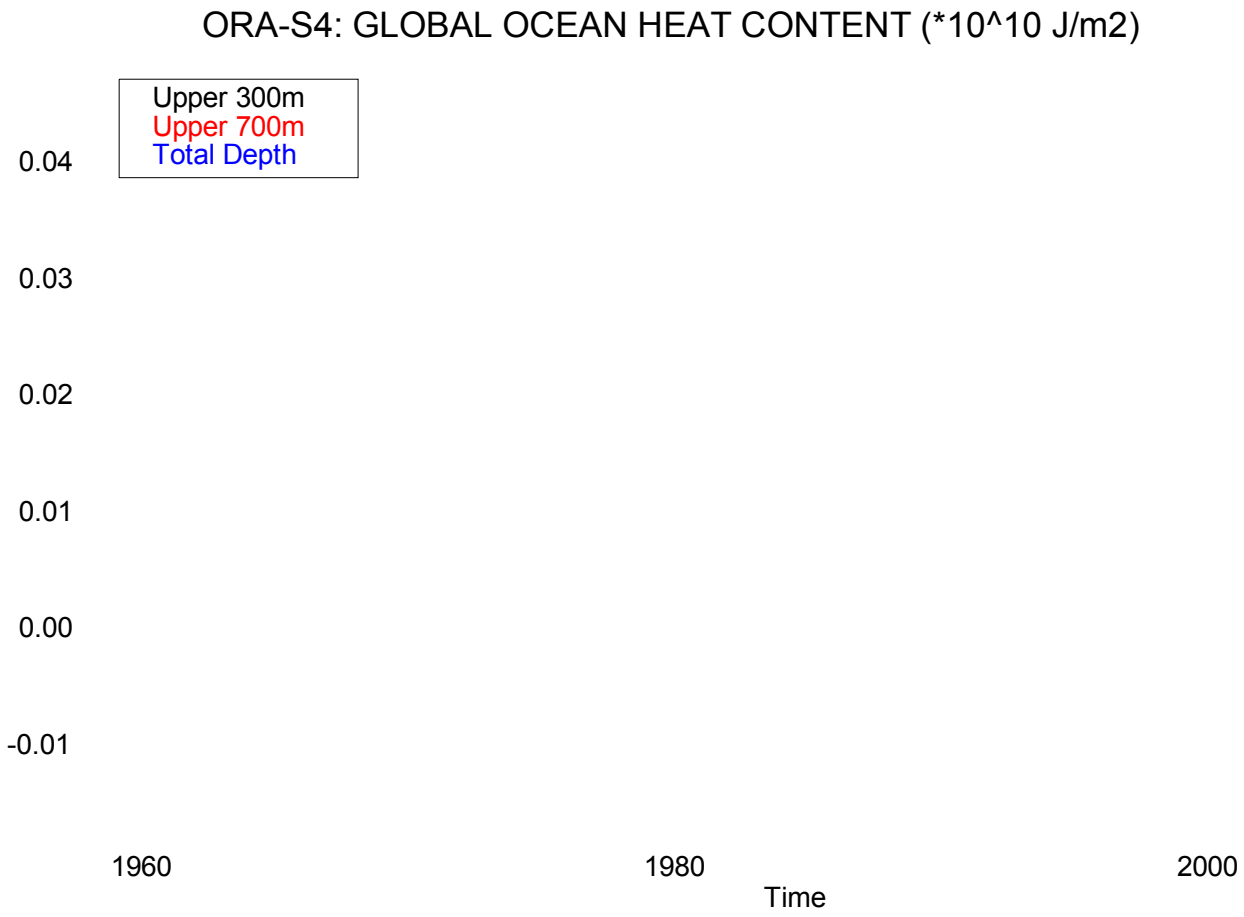


Sys3

Reliability diagram for ECMWF with 11 ensemble members
Near-surface air temperature anomalies above the upper tercile
Accumulated over Europe (land and sea points)
Hindcast period 1981-2010 with start in May average over months 2 to 4
Skill scores and 95% conf. intervals (1000 samples)
Brier skill score: 0.031 (-0.045, 0.094)
Reliability skill score: 0.943 (0.891, 0.965)
Resolution skill score: 0.089 (0.056, 0.133)

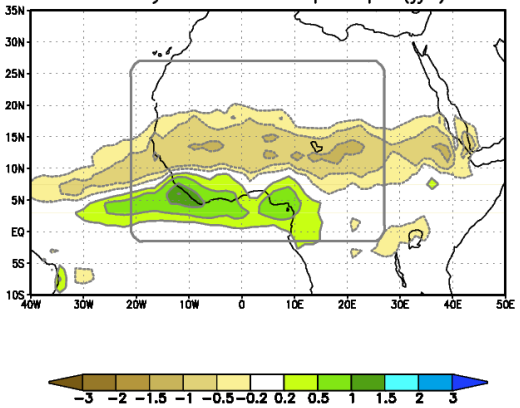


Decadal variability in ocean heat content from ORA-S4

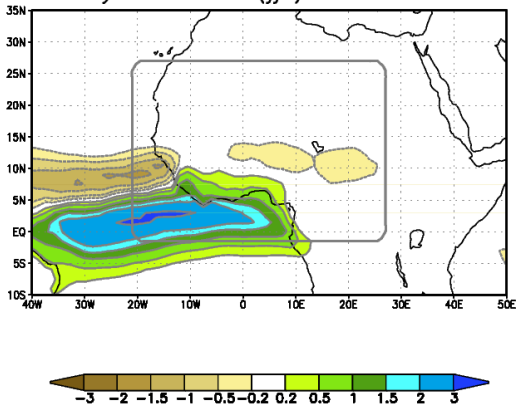


Variability of tropical rainfall: EOF comparison

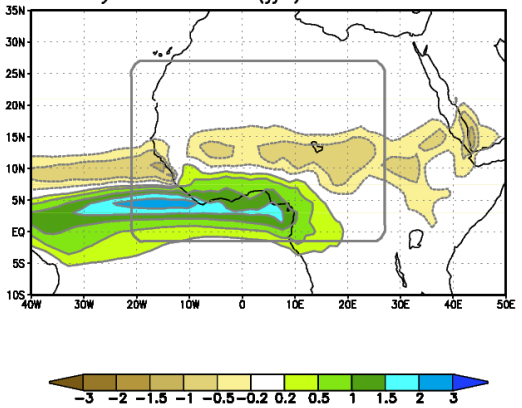
era28y EOF−1 of precip. (jja)



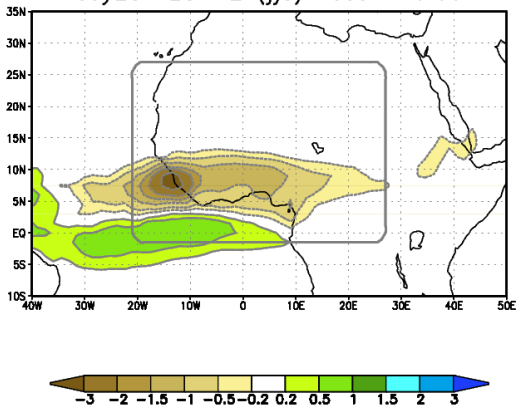
s3y28 EOF−1 (jja) acc = 0.33



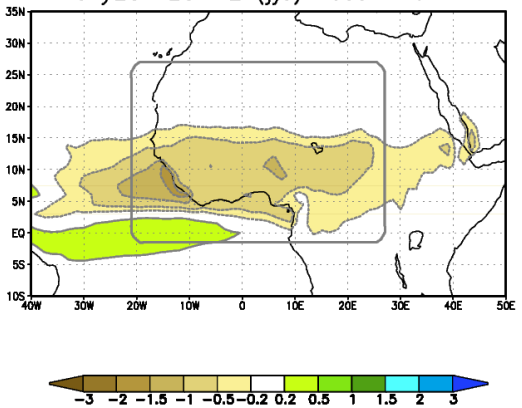
s4y28 EOF−1 (jja) acc = 0.71



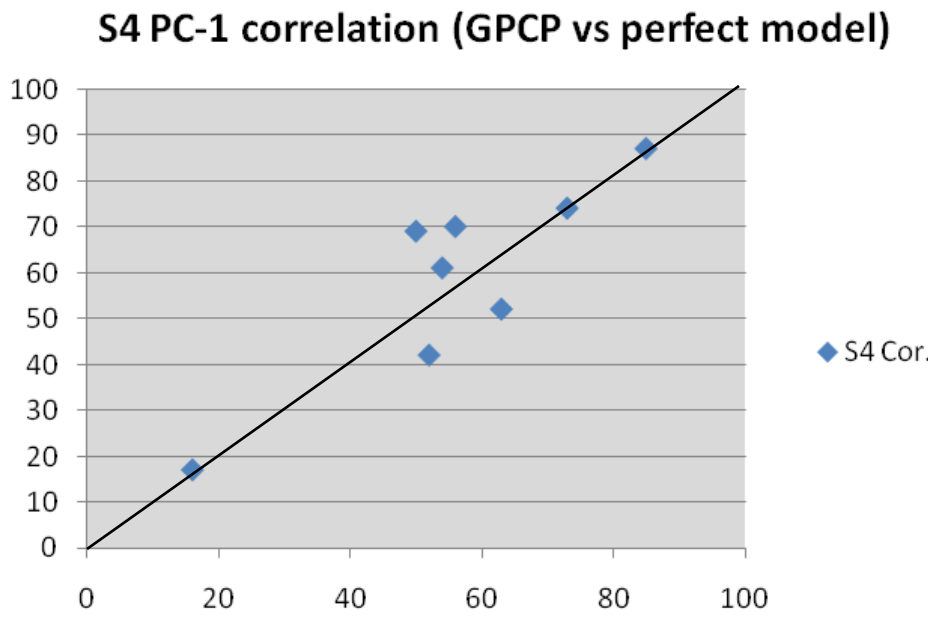
s3y28 EOF−2 (jja) acc = 0.00

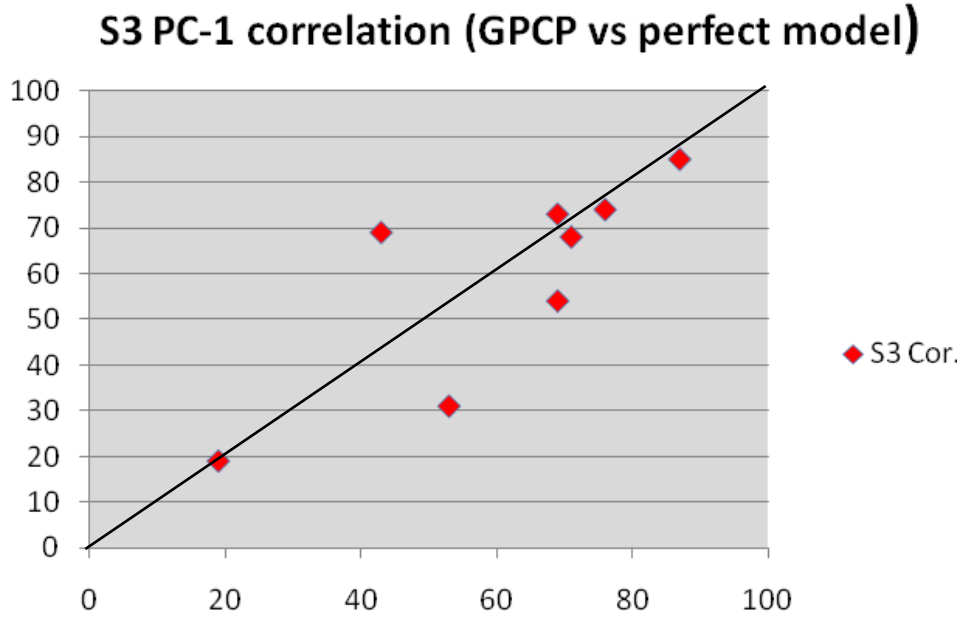


s4y28 EOF−2 (jja) acc = 0.44

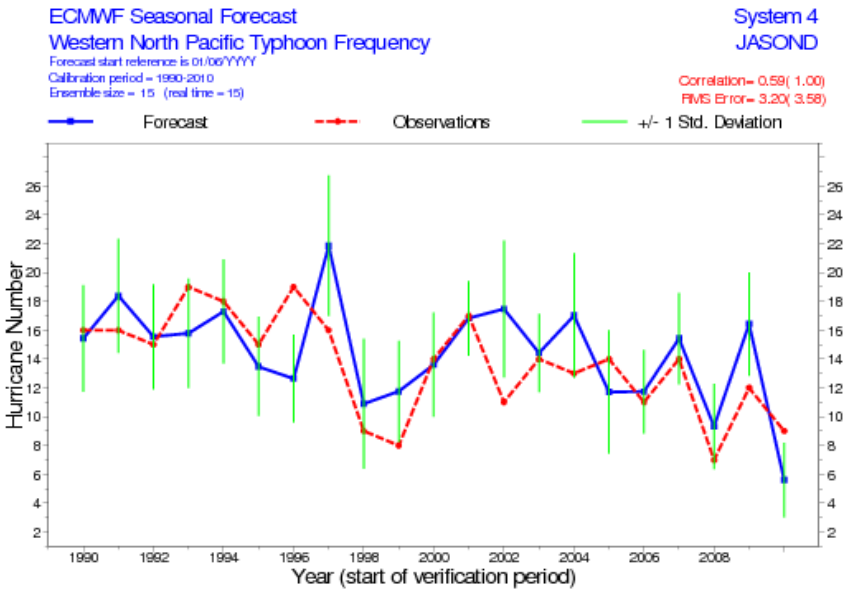


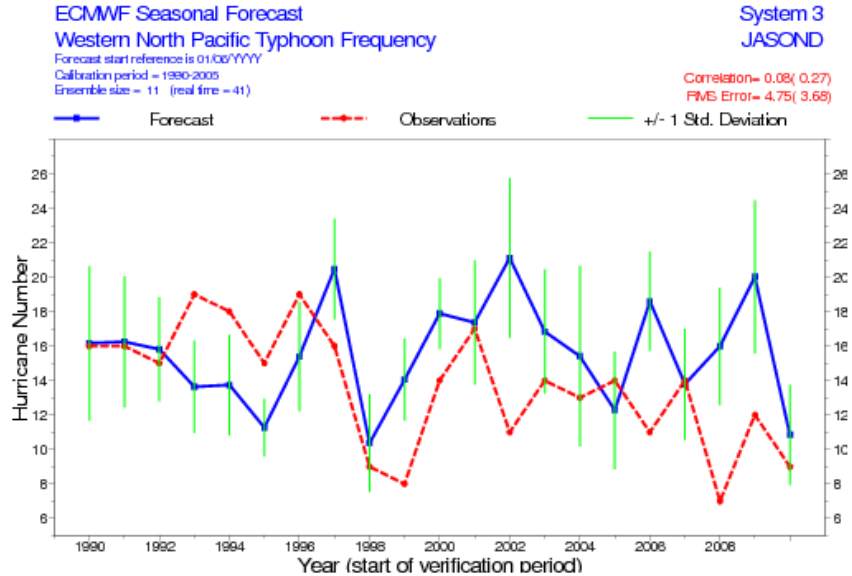
Actual vs. perfect-model skill: rainfall PC-1





Prediction of tropical cyclone frequency: NW Pacific

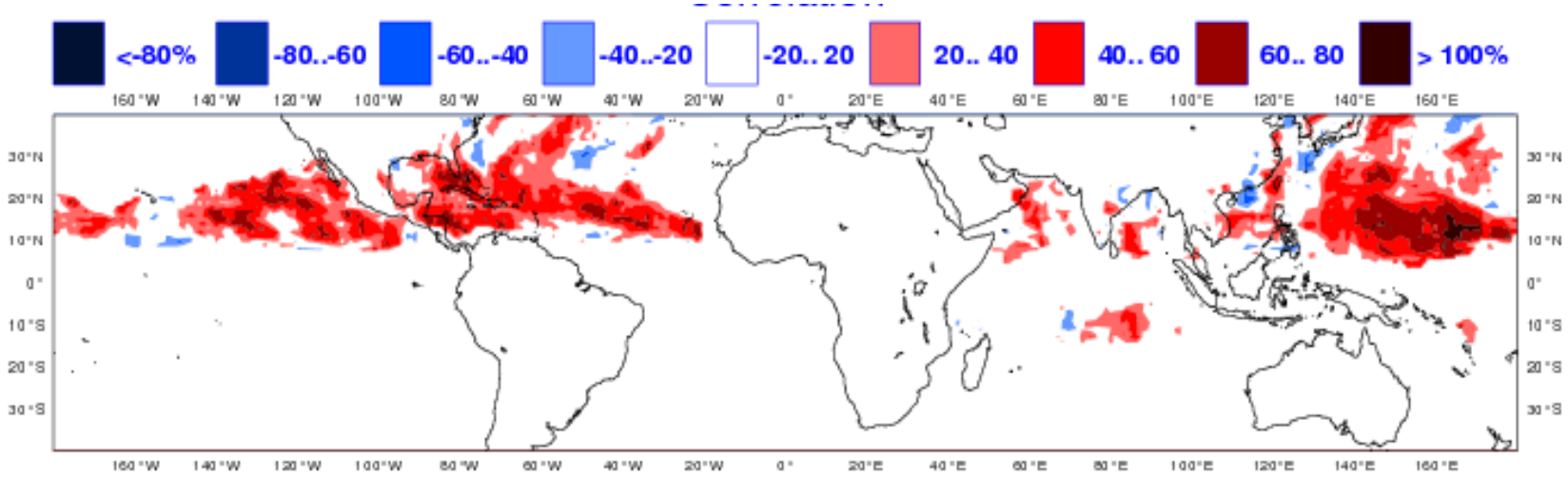




System 4

System 3

Verification (ACC) of cyclone track density in S4



Conclusions

- ECMWF has developed a new seasonal fc. system (Sys-4) based on an IFS-NEMO coupled model and a 3-D var. ocean data assimilation (NEMOVAR) , with higher spatial resolution and an extended re-forecast set.
- The IFS-NEMO coupled model shows reduced extra-tropical biases, but is affected by too strong easterlies and a cold SST bias in the Equat. Pacific cold tongue. ENSO variability is over-estimated, with max at fc. month 3-4.
- SST forecast skill is similar to Sys-3 in the NINO regions (better in NINO3, slightly worse in NINO4), increased in the tropical and sub-trop. Atlantic, but degraded over the West Pacific at long lead times.
- Spatial averages of ensemble-mean scores for atmospheric variables are higher than in Sys-3 at all seasons (NH summer better than winter).
- Tropical atmospheric variability is better simulated; this shows in more realistic patterns of rainfall variability and better simulation of the interannual and decadal variation in tropical cyclone frequency.
- The enhanced internal variability and better match between spread and error lead to more reliable forecasts in the seasonal range, even when deterministic scores are not significantly improved w.r.t. Sys-3.

Beyond System 4

- Higher resolution ocean model (NEMO 0.5/0.25 deg., L75)
- Dynamical sea-ice model (LIM-2 or LIM-3)
- Better initialization and perturbation of land-surface variables
- Improved representation of stratospheric processes and forcings
- Revised coupling strategy to improve code efficiency with high-resolution ocean model
- Closer connection between atmospheric and oceanic ensemble data assimilation